The Design and Implementation of a High-Density Surface Electromyogram Sensor Array for Neural Control Applications

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Abstract

Surface electromyography (sEMG) has long been a useful diagnostic tool for muscle and nerve conduction studies, and have recently become of interest for use in human computer interface (HCI) systems, due to their non-invasive nature and ability to be used in many locations on the body. sEMG technology operates by recording the electrical impulses generated within a muscle due to a chemical chain reaction which propagates from the motor cortex via a nerve pathway called a muscle unit (MU) to the innervated muscle. The muscles which control finger movement, the extensor and flexor digitori, are innervated by several MUs, each of which controls only one finger. Fortunately, each MU has its own ‘fingerprint’, therefore, the raw filtered data can be separated into its individual MU components. The raw sEMG data is fed into a feature identification algorithm which is used while training the system.

Designing a High-Density sEMG Array

We chose to use a high-density sEMG array in order to harness the spatial, as well as the temporal, data to facilitate MU decomposition, and we decided that a flexible sensor would make even contact with the skin. The flexible unibody design also allows it to be worn as a simple arm cuff, and also standardizes the relative electrode placement, providing more consistency in the recorded data.

Constructing the Array

We are building our sensor array in-house, using a novel wet chemical etching process which uses a Xerox® Phaser® 8650N solid ink printer to print wax directly onto a sheet of DuPont™ Pyralux® AP9121R, which is a three-layer laminar composite of 50.8μm polyamide film (a dielectric) sandwiched between two layers of 35μm copper foil. The wax resists the etchant, and protects the underlying copper from the corrosive acid. Unfortunately, the printing process requires the two sides of the board to be printed and etched separately, so a film is adhered to the non-working side to protect it as well. Due to the smoothness and rigidity of the Pyraluz material causing printer jams, the leading edge of the Pyraluz was cut to a point and a lead of Kapton polyamide film was adhered with cyanoacrylate to pull the sheet through the printer. Kapton was used due to its strength and chemical stability, allowing it to remain adhered while etching.

Building the Circuit

Due to the complexity of this project, the system is not currently operational, though most of its components are nearing completion.

The sensor array is likely the closest to completion; we must identify the cause of the poor wax adhesion to the copper surface, as wax has been chipping off during the etching process, exposing vital copper traces. Once that sensor is overcome, it is a simple matter of drilling thru-holes and soldering on the Ag/AgCl electrode pellets.

We need to continue research on SVM operation to better understand how to implement and apply it to recognizing motor unit features.

We will eventually convert the sensor array to an active board, housing all amplification and A/D circuitry on-board, including Konstantin Avdashchenko’s PIC chip. The MatLab code running the processing algorithm and SVM will be migrated to C code and will run on the PIC chip, finally consolidating the entire system onto the sensor cuff.